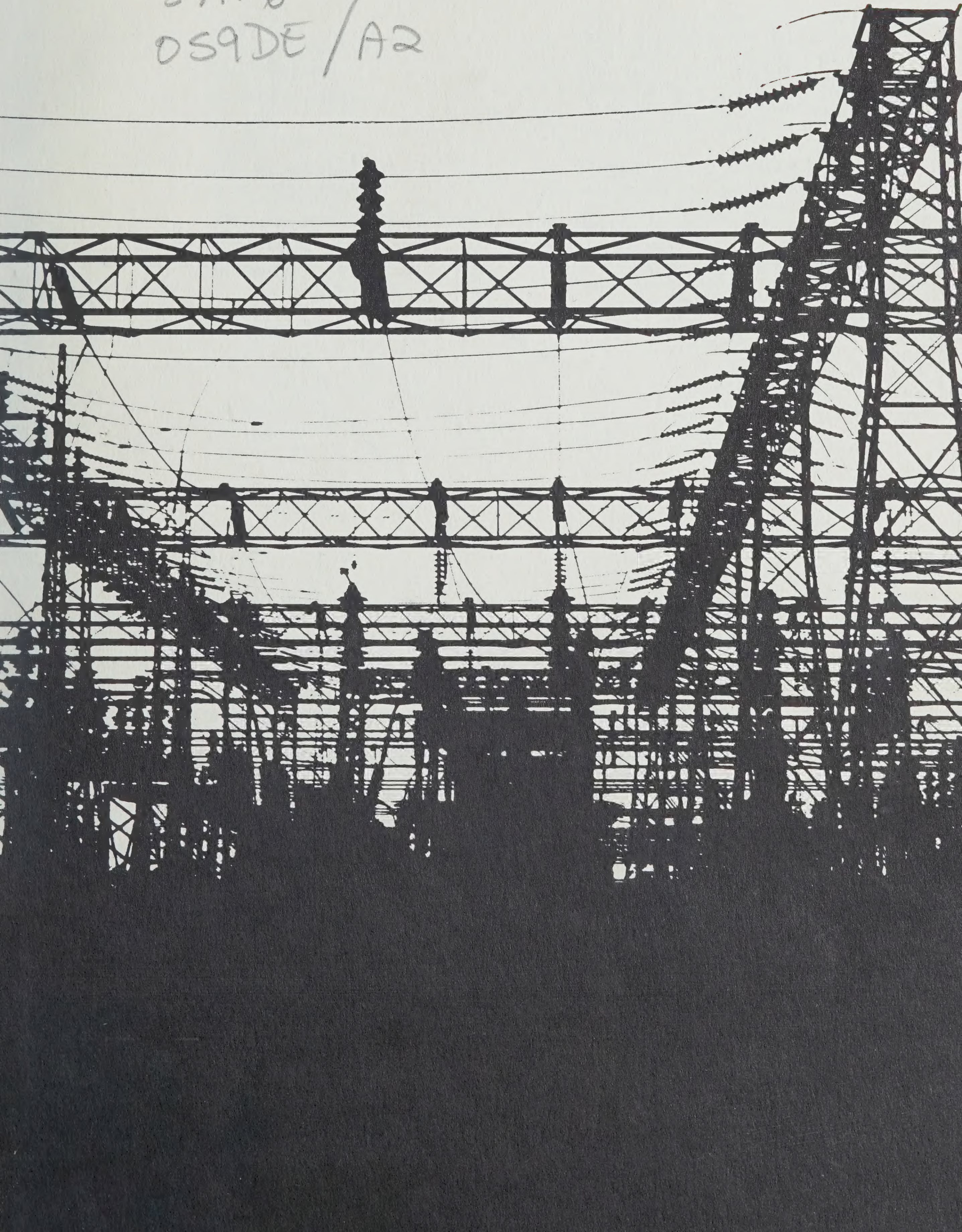
Ministry of Education
Ontario

Minister of Education
Hon. Thomas L. Wells

Electrical Work in Schools



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Prepared by
Architectural Services-Planning
in conjunction with
Rybka, Smith & Ginsler,
Electrical Engineers

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Introduction

Most buildings rely on electricity for lighting, power, signals, and other communications. Electric energy is also used for heating and year-round thermal conditioning of spaces. Its ease of transmission, simple control and measurement, and relative safety make it a useful source of energy.

This publication is not intended to be a handbook for the consulting electrical engineer. Its intent is to provide those persons responsible for the provision and operation of educational facilities with a general description of the present state of accepted electrical design for schools and to give some indication of future trends.

General Considerations

The Utility
Ontario Hydro is responsible for the generation and transmission of electric power in the Province of Ontario. The retail distribution of this power is generally the responsibility of the various municipal electrical utilities that own and operate the distribution systems within their respective areas. These local utilities obtain their supply of power from Ontario Hydro at cost under contract arrangements.

Ontario Hydro owns and operates "Rural Hydro" serving farmlands and cottage areas in addition to certain built-up unincorporated areas, where distribution costs are high in comparison to revenue.

The respective duties and responsibilities of Ontario Hydro and the local municipal electrical utilities are outlined in two acts of the Ontario legislature–The Power Commission Act and The Public Utilities Act.

The Code
The Electrical Safety Code and Ontario Hydro supplements are the standards of requirements for electrical installations in Ontario buildings. Their purpose is to ensure safety. In this regard, they establish essential requirements and minimum standards and make provisions for the prevention of fire and the promotion of proper operation and maintenance.

Inspection
The basis of inspection is The Electrical Safety Code and any supplementary regulations issued periodically by the Inspection Department of Ontario Hydro. This department consists of the head office, which is responsible for standards and policy, and local offices throughout the province, which are responsible for on-site inspections of all new or altered electrical installations.

Requirements
Construction plans must be submitted to the Inspection Department of Ontario Hydro for approval. Each project is inspected, and the electrical work is subject to approval as the actual construction progresses. A certificate of approval is issued upon completion. Permanent electrical power is not connected until the Inspection Department has approved the installation.

The electrical contractor is normally required to arrange for the inspections, pay any necessary fees, obtain the certificates of approval, and present them to the owner.

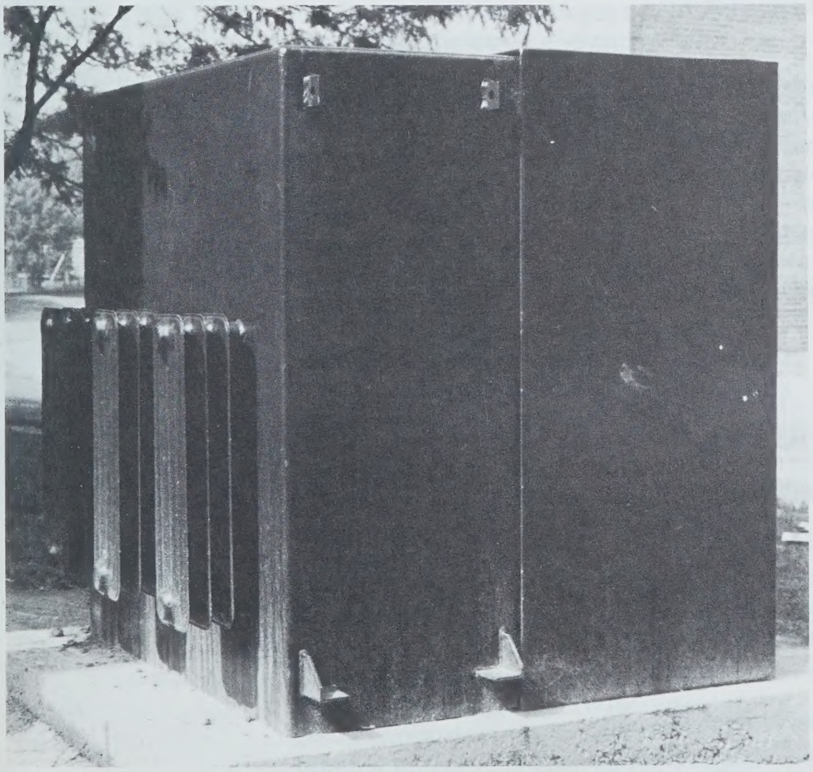
The building owner should ensure that conformity to the Code is adhered to throughout the life of the building by insisting that any electrical additions to a building or modifications to existing equipment are inspected and approved by the Inspection Department of Ontario Hydro.

Electric Services

An electric service is that part of a building's electric system that connects the utility's distribution system to the building's distribution system It includes such items as connecting conductors, a disconnecting switch with protective over-current devices, and metering apparatus. It may also include transformation facilities.

Local utility policies with respect to service arrangements may offer the customer some choice. If the building's electrical load is small, service may be obtained at secondary or utilization voltage. For larger loads, the utility may require the customer to take primary or high-voltage service. In some cities of Ontario, a distribution system known as Network is available.

Network
This service arrangement consists of utility-owned transformer vaults located under the sidewalks, from which secondary services of whatever voltage required are provided by the utility. These are interconnected to provide reserves against overloading any part of the system.



Transformer

Secondary Service
One such arrangement is through overhead service conductors. The utility usually provides without charge up to one hundred feet of these conductors within the property line. Many municipalities, however, now require that underground services be installed. In some cases, the extra cost thus entailed, or a portion thereof, is paid by the building owners.

Primary Service
This arrangement involves high-voltage conductors, sometimes underground; a transformer with a primary switch and overload protection inside or outside the building; larger secondary conductors from the low-voltage side of the transformer to the main secondary switch; and lightning protection. The building owner normally pays for all of this equipment.

Where the utility provides the transformer, it will invariably be oil-cooled. If located inside the building, a transformer vault must be provided. It must be constructed in accordance with Code requirements to withstand possible transformer explosion and to confine any resulting fire.

If the owner must provide the transformer, an outdoor, pad-mounted transformer, complete with primary protection and a vandal-proof steel enclosure or chain-link fence, will be the cheapest form of service arrangement available to him. Where indoor installation is required, air-cooled transformers should be considered. Although they are somewhat more expensive than the oil-cooled variety, no special vault is necessary; thus there is an overall saving.

For those institutions that require loads greater than, say, 300 or 400 kilowatts, larger equipment is necessary, and anything other than outdoor mounting is extremely expensive.

Transformers are noisy; they emit a hum of 60 to 70 decibels. Their location and arrangement with respect to the school itself and the buildings nearby should be carefully considered.

Masonry walls around the transformer installation and a location at a reasonable distance from all buildings will substantially reduce the noise problem.

Service Arrangements

The following table indicates what may be expected in the way of service arrangements.

Load	*Type*	*Voltage*
to 150 KW	secondary service	120/240, 120/208, or 600 volts
any size network area	secondary service	120/208 or 240/416 volts
150–400 KW	primary service	4 KV to 8 KV
over 400 KW	primary service	12 to 44 KV

Meters

Meters form an integral part of the electric service and are provided by the utility. They are subject to government regulations regarding design and accuracy and are of two types:

–Primary meters are costly to the utility and are normally only used for very large loads.

–Secondary meters are used for all secondary services and most primary-service installations. They are located on the building side of the secondary-service switch. These meters operate at lower voltage and thus are less expensive.

For all but the smallest rural schools, the meters will measure and record two quantities: the maximum demand, being the largest flow of electricity in kilowatts through the meter to the building over any thirty-two-minute interval during the billing period (usually one month); and the consumption of electricity over the metered period in kilowatt hours.

Rates

Recently, there has been a simplification of rate structures throughout Ontario. Previously, a number of different rates applied to the same building – one for lighting, one for power, and one for cooking. Now, a single rate usually exists to cover all usage in the building. This arrangement is beneficial to the building owner in that the building wiring system is simplified and requires less sub-division and only one metering station.

Electricity is sold to all non-residential users on the basis of demand and energy consumption. The rates are designed to favour the user who consumes energy at a more constant amount per hour throughout the billing period. Such a user will have a lower cost per kilowatt hour.

Conductors and Protective Devices

Conductors, depending on their size, have a definite maximum amount of current that they can carry without overheating and ultimately melting. The proper current-carrying ratings of the different sizes and types of conductors and protective devices for use in various situations are outlined in The Electrical Safety Code.

An electric conductor of insufficient size for the required load will tend to overheat and thereby constitute a definite fire hazard to the building. Protective over-current devices are employed to interrupt the flow of electrical energy and cut it off when the current rating of the conductor is exceeded. These devices also protect against short circuits flowing through faults in the system.

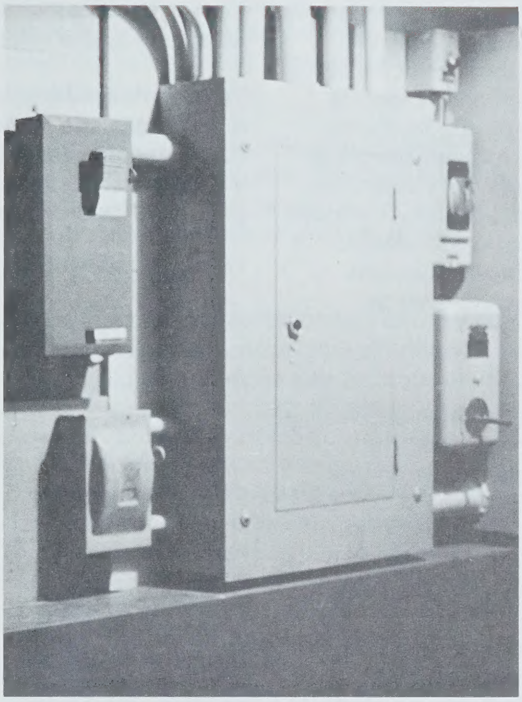
A system is said to be properly co-ordinated when the protective device immediately on the supply side of a fault opens, isolating the fault. Further protective devices upstream should not open, so that only the faulty part is shut off and made dead. The protective devices in a system should be designed to operate in this way.

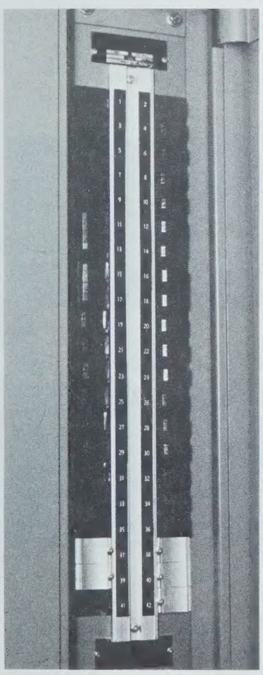
Ground-Fault Protection

It is possible for an electrical system to be apparently correctly installed and still be in a dangerous condition. An example of this is the case of a school with metal relocatable partitions. These partitions may become energized by ground leakage, without properly discharging the current to the ground. In this situation, it is unlikely that normal over-current devices will provide any protection. For this reason, consideration should be given to the inclusion of ground-fault protective devices. This equipment is expensive, but it has already been made mandatory by Code authorities for installations such as swimming pools.

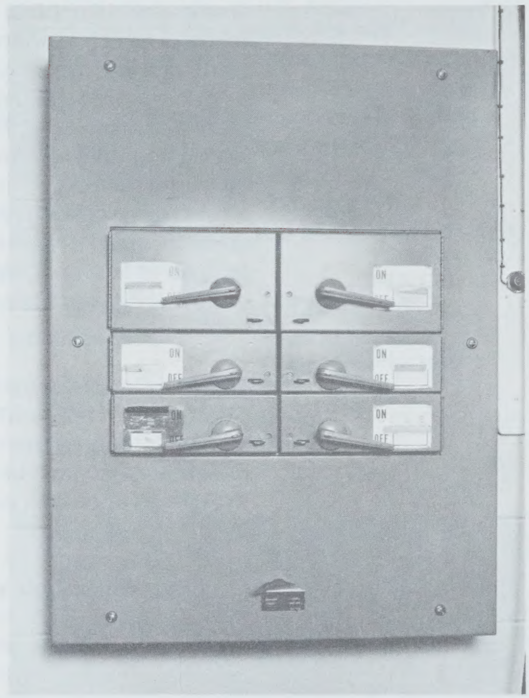
Distribution System

Below: Main switchboard
Top left: Emergency stop button
Bottom left: Lighting panel





Shop panel



The distribution system is the means of conveying electric energy throughout the building – from the service entrance to the lighting fixtures, electric motors, electrically powered equipment, appliance, and convenience outlets. A typical system consists of a switchboard fed by the electric service with outgoing branch mains to lighting panels, shop panels, and electric motors.

Switchboard
The main switchboard contains the main service switch controlling incoming power, the metering apparatus, and the branch switches for each of the outgoing branch mains. Each of the switches, main and branch, incorporates a protective device with a rating based on the conductors it serves.

Lighting Panels
The outgoing branch mains serving the lighting system terminate in lighting panels, with up to forty-two branches in each panel, from which branch wiring extends to the lighting fixture outlets.

Electric Motors
Electric motors have special requirements for protection against overload or overheating because they are characterized by a higher energy requirement for starting than for their normal operating speed. For this reason, they require a motor starter that will permit a higher current flow for a short time (measured in seconds) and subsequently a lower value of protection as they continue to run.

Shop Panels
Where laboratories and/or workshops are essential in the educational program of a school, such spaces usually have permanently installed equipment that requires more or less elaborate electrical installations for power and control.

The panel serving the equipment should be separate and under the control of the teacher. In learning areas used for sewing, typewriting, or accounting, the panel may be built into the teacher's desk. Where the panel is too large for desk mounting, as is likely in woodworking or metalworking shops, wall installation adjacent to the teacher's station is recommended.

Shop circuits must have a light indicating when they are energized, as well as one or more emergency stop buttons, usually located at the teacher's station and at the normal exits.

The branch-wiring circuits in the panel should be clearly labelled to indicate the piece of equipment being served.

One of the major parts of the electrical contract work, both in importance and in cost, will be for lighting systems in the school. Lighting as a design element can enhance or define parts of the building. The role of the illuminating engineer will be to provide designs to give light for the performance of visual tasks with a maximum of speed, accuracy, ease, and comfort, and a minimum of eye strain and fatigue. In addition, lighting can be used to define different spaces and even to evoke mood.

Design Considerations
The design of any lighting installation involves a consideration of many variables. The questions that must be asked to determine the design approach are:

– What is the purpose of the installation, i.e., is light for critical seeing tasks, for decoration, or for other reasons?
– How severe is the seeing task and for what length of time is it to be performed?
–What economic considerations are involved?

The answers to these questions will determine the amount of light that should be provided and the best means of providing it. The solution will involve individual tastes and opinions, especially in matters of appearance; no one solution to lighting will be the most desirable under all circumstances.

In all teaching areas of the school, many different tasks will be carried out. It is most important that the lighting be carefully designed to provide the correct quantity and quality of light and to integrate it properly into the building's design.

Quantity of Light
To light a specific area, it is important that an appropriate number and size of fixtures be employed and that the spacing between the fixtures be not too great. If the distance between fixtures is excessive, the distribution of illumination will be irregular with good lighting provided directly below fixtures and inadequate lighting between them. The mounting height of the fixture will also be an important factor in determining fixture spacing. In some locations, for certain types of tasks, it might be advantageous to concentrate light over the work area. In other locations, non-uniform levels of illumination may be desired. Special designs should be developed to obtain the proper effect.

The quantitative unit of measurement of light is the footcandle. The following table indicates the illumination levels that may be expected in the normal spaces encountered in a school; it provides a guide to good present-day practice.

Levels of Illumination for Schools*

Area	*Foot-candles on Tasks*	*Dekalux # on Tasks*
Art rooms	70	75
Cafeteria	50	54
Corridors and stairways	20	22
Drafting rooms	100	110
General learning areas	70	75
Gymnasiums	30–50	32-54
Home economics–		
a) sewing	150	160
b) cooking and ironing	50	54
Laboratories	100	110
Lecture rooms–		
a) audience area	70	75
b) demonstration area	150	160
Library	70	75
Lounges, rest-rooms, lockers, showers, and washrooms	20–30	22–32
Offices	70–100	75–110
Seminar rooms	70	75
Shops	100	110
Study halls	70	75
Typing rooms	70	75

*Adapted from the "Illumination Engineering Society Recommendations" in the IES *Lighting Handbook*, 5th Edition.

Quality of Light
Adequate quantity of light alone does not ensure good illumination. Good quality is as important as quantity and usually more difficult to achieve. The factors involved in obtaining good-quality lighting in any given space are many and complex, but glare, brightness ratio, diffusion, and colour are some of the most important.

Glare is any brightness that causes discomfort, interference with vision, or eye fatigue. Glare is difficult to measure but will be related to the brightness of the source, the size of the source, the position of the source in respect to the usual lines of vision, the brightness contrast (brightness of the glare point as contrasted with the adjacent surfaces), and the time over which the glare is encountered.

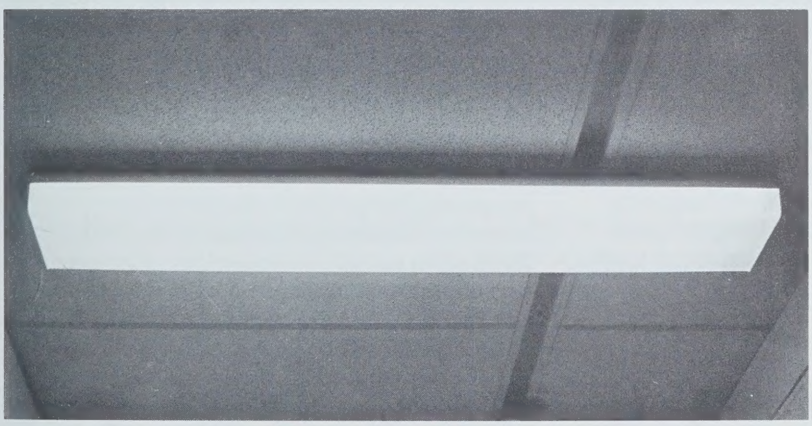
Another problem is the reflected glare from shiny surfaces such as polished desk tops, machine metal, cellophane sheets, glossy

paper, etc. Wherever possible, care should be taken in locating the light sources with reference to the working plane to eliminate this effect.

Excessive "brightness ratios" in the field of vision are also undesirable. The ideal situation for critical seeing is to have a background brightness equal to the brightness of the task itself.

The colour of light has little effect on the visual efficiency. For the performance of ordinary tasks, no light source has an advantage over others from the standpoint of colour. However, in some specialized applications (notably colour matching, colour discrimination processes, and the like) light source and colour output will be a factor in illumination quality.

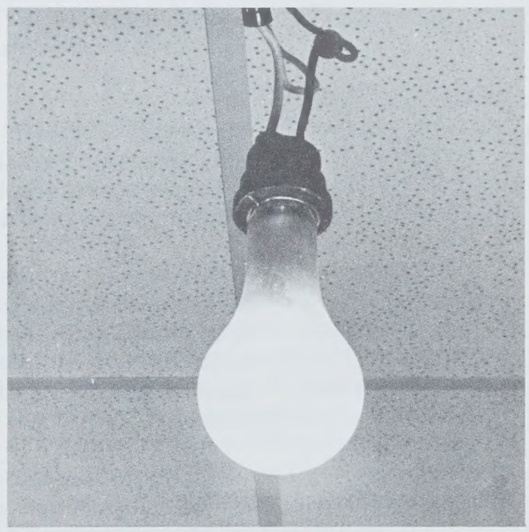
Many recently constructed schools are air-conditioned. Since the heat generated by the lighting fixtures is an appreciable portion of the air-conditioning load, the light source with the lowest heat generated per lumen of output per unit of energy input should be considered. In most cases, fluorescent lighting will be the most appropriate source to use, wherever possible.



Fluorescent fixture

The efficiency with which a light source fulfills its purpose is expressed in terms of lumens transmitted per watt of power consumed. The main types of lamps that will be encountered in school lighting are incandescent filament, fluorescent, mercury, and metallic vapour. Some indication of the efficiency of these lamps can be given by comparing the lumen outputs per watt of power consumed for each.

Type of lamp	*Lumens per watt*
incandescent	15 to 23 approx. (depending on type)
fluorescent	72
mercury	60
metallic vapour	100



Top: Incandescent lamp
Bottom: Mercury vapour fixture

Operating Characteristics
To determine which is the most appropriate lamp for the job at hand, some knowledge is required of its operating characteristics. The following are some considerations:

–the colour of the light source from the point of view of the apparent colour of the lamp as well as the colour rendition at the working surfaces below the lamp

–the cost of the lamp per lumen of light received

–the physical dimensions of the lamp

–maintenance considerations such as lamp life. Approximate lamp life of incandescent lamps is 1000 to 2500 hours, fluorescent lamps 7500 hours, and mercury lamps 25,000 hours

–the effect of ambient temperature on the lamp operation. For example, fluorescent lighting output is seriously reduced if the ambient temperature drops below 30°F

–incandescent lighting. It can be readily dimmed with standard dimming equipment; fluorescent lighting requires special dimming ballasts as well as dimmer equipment, which is expensive. Dimming of mercury fixtures is impractical

–the operating considerations. Fluorescent lamp life, for example, is seriously reduced if the fixture is switched on and off frequently. Mercury lamps are very slow in lighting and this may be a problem if immediate high levels of light are required.

The following are some comments and advice regarding lighting layouts in the typical spaces that will be encountered in school construction.

Learning Area
This is a space of approximately 750 square feet, and the lighting should provide good levels of illumination.

Good illumination levels for difficult tasks vary. The following chart shows some recommended levels.

Activity	*Footcandles*
audio-visual	30 (for note-taking)
drafting and bench work	100
reading pencil material	70
reading duplicated material (poorly produced)	100
sewing	150

It will generally be found that to provide the above levels of illumination, fluorescent fixtures are the most practical source. The question then arises as to whether the fixtures should be recessed into the ceiling, surface-mounted, or suspended. In many cases, the fire rating of the ceiling will dictate whether recessed fixtures can be used. If a recessed fixture is used, then an acceptable enclosure above the fixture will be required to maintain the fire rating of the ceiling.

Suspended fixtures should have an upward as well as a downward component of light so that ceiling surfaces adjacent to the fixture receive good illumination. In this way, the contrast between the bright source of the fixture and the adjacent surfaces is reduced. These fixtures should be carefully selected to ensure that shielding is provided so that the light source cannot be be seen directly from the normal viewing angles.

It is most important that good illumination be provided on chalkboard surfaces. This can be obtained by locating the standard ceiling fixtures in such a manner that there is a row of fixtures close to the chalkboard, or by providing a special ceiling or wall-mounted fixture directly over the chalkboard. The latter provides the best chalkboard illumination.

The switching of the lighting fixtures in the learning area should be carefully planned, with separate switching provided for chalkboard lighting. The main lighting in the room should

Suspended fluorescent fixture

Coffered lighting–ceiling

be switched in such a manner that when darkened for audio-visual presentations, reasonable illumination can be maintained over students' desks for note-taking.

Care should be taken in locating the fixtures to ensure that they are properly co-ordinated with movie screens, TV monitors, etc., and that chalkboards or tackboards are not obstructed from view by suspended fixtures.

It is recommended that samples of the proposed fixtures should be reviewed and an inspection carried out to ensure convenient maintenance access to the fixtures before the specification is finalized. If plastic components are used, then acrylic plastic should be specified rather than styrene in order to minimize breakage from brittleness and yellowing with age.

The number of different types of fixtures used throughout the school, especially the fluorescent fixtures, should be kept to a minimum. This will ensure the lowest per-unit cost during tendering and will also simplify maintenance procedures.

Open Learning Spaces
Fixtures in this type of space provide the necessary illumination levels on a modular basis so that partitions, if required, can be erected without changes to the arrangement and number of fixtures in each space. Normally, panel switching will be used for these fixtures, and, if partitioning occurs, additional local switching can then be installed.

Corridors and Lobbies
Recent experience in schools has shown that fairly high levels of fluorescent lighting are desirable in corridors to provide good levels of illumination and a bright and cheerful effect. This can be effected by installing standard fixtures down the centre of the corridor or by creating cove lighting along the perimeters. In lobby areas, the architect may suggest decorative lighting because of the special architectural finishes in these locations. It is recommended that corridor lighting be switched from panels. There will be a lighting requirement for staff access to the panel if lights are switched from the panel. It may be desirable to leave a number of fixtures on in the corridors throughout the night; these should be installed on separate circuits. These may also be used as emergency lighting by providing both a main and a secondary power supply to them. An automatic transfer arrangement would then be required.

Gymnasium using mercury vapour fixtures

Industrial fixture

Washroom, Locker, and Shower Rooms
Good overall illumination is recommended in these areas to encourage cleanliness. Fluorescent lighting is highly recommended. Switching of lighting in these locations should be controlled from the lighting panel or by a key switch in the room to discourage tampering with the switches.

Gymnasium
The amount and type of lighting to be provided in a gymnasium will depend on usage. For exhibitions and matches, 50 footcandles are required. For general exercise and recreation without spectators 30 footcandles would suffice.

These levels would apply for basketball, badminton, and similar sports.

Incandescent, fluorescent, or mercury lighting can be used for gymnasium lighting. The fixture chosen should have wire guards or rugged protection against damage by baseballs, basketballs, etc. As the mounting height of the fixtures will be fairly high in most cases, the method of relamping of the fixture should also be considered. Fluorescent lighting is one of the more economical and prevalent methods of providing gymnasium lighting. Recently, however, mercury lighting has been used with some success. The brightness of the light source should be carefully considered and kept to a minimum, especially for sports such as tennis or badminton.

Shops and Laboratories
These areas will often be spaces without suspended ceilings and will require an industrial type of fixture. If there is any danger of the lamps being damaged by the work involved, protective wire screens should be installed over the fixture. If vibration is anticipated, which may present a problem with incandescent lamps, a special socket should be installed to ensure that the lamps do not vibrate loose.

Gymnatoriums and Cafetoriums
These areas present a problem in that they will probably have a variety of uses, including classroom work or individual study work where learning area levels of lighting will be required. For assembly or exhibition purposes, levels of 15 to 30 footcandles will be adequate. Dimming may be a requirement so that different levels of light can be provided for use with projectors or TV monitors, at which time lighting may have to be reduced to allow proper viewing while at the same time providing sufficient light for note-taking. A preferable method of lighting such areas is to

provide incandescent lighting on dimmers, for assembly and exhibition purposes, supplemented by fluorescent lighting on switches, for higher levels of classroom lighting. A flexible arrangement for the accent lighting would be to provide a track into which fixtures can be plugged as required to suit the job at hand. In a cafetorium or gymnatorium, stage lighting and power provision, along with a dimmer system, should be considered. The degree of sophistication will depend on the proposed usage. In any case, power should be provided so that, if dimmer and stage-lighting provisions are not installed initially, portable systems could be rented and installed for infrequent stage productions. The method of relamping of the fixtures should be considered, as ceilings in these spaces will be relatively high.

Library
In libraries high quality lighting and good levels of illumination are recommended with approximately 70 footcandles at the work surface. A decision should be made as to whether book stacks will be permanent as this will radically affect the lighting arrangement. If movable stacks or shelves are to be used, these should be terminated sufficiently below the ceiling so that a general lighting pattern in the room will provide adequate lighting of the stacks.

Exit and Emergency Lighting
Exit lights are required and should clearly define the exit routes. There should be fixtures installed over all exterior doors to assist in fire evacuation of the building.

Emergency lighting should also be provided along all evacuation routes, stairwells, and in larger areas such as open learning areas, the cafetorium, gymnasium, etc. Battery units will normally be the most appropriate type of lighting to use here. These can be central batteries with several remote fixtures or, alternatively, if the fixtures are spread out over a large area, individual self-contained units can be employed. These should contain an automatic charging facility as well as automatic transfer to the battery in the event of a power failure. The type of battery should be considered from a maintenance point of view. Nickel cadmium batteries, although more expensive initially, require considerably less service than the less expensive lead-acid type of battery. Larger schools should consider a stand-by motor generator set if the requirement for emergency power is great, or if the school includes such items as elevators.

Standby motor generator

Outside Lighting
Outside lighting may consist of an illuminated sign, roadway lighting, and, if there is insufficient spill-lighting from adjacent municipal roadway fixtures, footpath lighting and parking lot lighting. Security lighting should also be installed by using an inconspicuous fixture to provide general lighting of the perimeter of the building, especially dark niches. Parking lot lighting, if adjacent to the buildings, can most economically be provided by floodlighting fixtures mounted on the walls or roof of the building.

Care should be taken in the design of all outside lighting, especially in residential districts, to ensure that bright sources are not an annoyance to the neighbours on adjacent properties.

Television
If TV videotapes are to be prepared in the school, then the audio-visual department should be consulted to determine the extent of special lighting provisions for their preparation. A wide range of provisions can be employed, depending on the sophistication of the work to be done.

Supplementary electric heating

Heading

There has been considerable interest in heating by electricity in recent years. A number of buildings in Ontario have been so equipped, with varying degrees of success.

The *advantages* of electric heating include the efficient use of energy, cleanliness, ease of local control, absence of requirements for attendance and operation, lower capital cost, and flexibility and adaptability to expansion or change.

In addition, electric-supply utilities may offer certain concessions to customers using electric heating, and where electricity is the sole energy purchased for the building. These concessions have included:

– a reduced rating (as from commercial to industrial);

– a utility-supplied transformer plant;

– provision of special controls to limit maximum demands (by shutting off the energy supply to certain sections of the system at times of high demand–in such areas as domestic hot-water heating and the heating of storage and garage spaces).

The major *disadvantage* of electricity as a heating medium is its higher cost (per heat unit) as compared to that of natural gas or fuel oil. This factor is significant in spite of the comparative inefficiency of a fuel-fired heating system. To ensure reasonable operating costs, it is recommended that heating energy be minimized by employing such design measures as increased building insulation, reduction of window areas, the use of double-glazed window units, and systems for the recovery of heat from the air before it escapes from the building.

These measures result in additional initial cost, and this cost must be set against savings in the capital cost of the electric heating system itself, if real values are to be made clear.

If electric heating is being considered for a school, a cost-benefit analysis should be carried out on the basis of the comparative cost for the total owning and operating energy, i.e., *the cost of a fuel and the electricity required for a fuel-fired system should be compared to the total cost for an electrical single-energy installation.*

This analysis needs to be exhaustive and should include such factors as:

– the features of architectural design that affect heating requirements;

– the heating system itself, including costs;

– the heat gains within the building from lighting apparatus and occupants;

– the expected schedule of operation and its effect on heat requirements;

– the reduction of the unit cost of electricity: longer hours of use and around-the-clock heating requirements lead to a lower real cost of energy used for lighting and power.

Such analysis is an involved process, even with the assistance of the technical expertise

Roof-top heating/cooling unit

maintained by Ontario Hydro to advise on electric heating. It is, however, a necessary exercise, since, due to the high cost of the energy, design shortcomings will make themselves apparent by the amounts shown in the first heating season's electrical bills.

Cooling

Modern educational facilities, due to their large volumetric spaces, high lighting levels (creating heat), extended hours of use, and compact design, create a demand for mechanical cooling.

Where mechanical cooling (frequently, if incorrectly, referred to as air conditioning) is to be incorporated into a school, a feasibility study should be carried out to consider the type of equipment to be utilized. Refrigeration may be provided by a reciprocating compressor, a centrifugal compressor, or an absorption refrigeration machine.

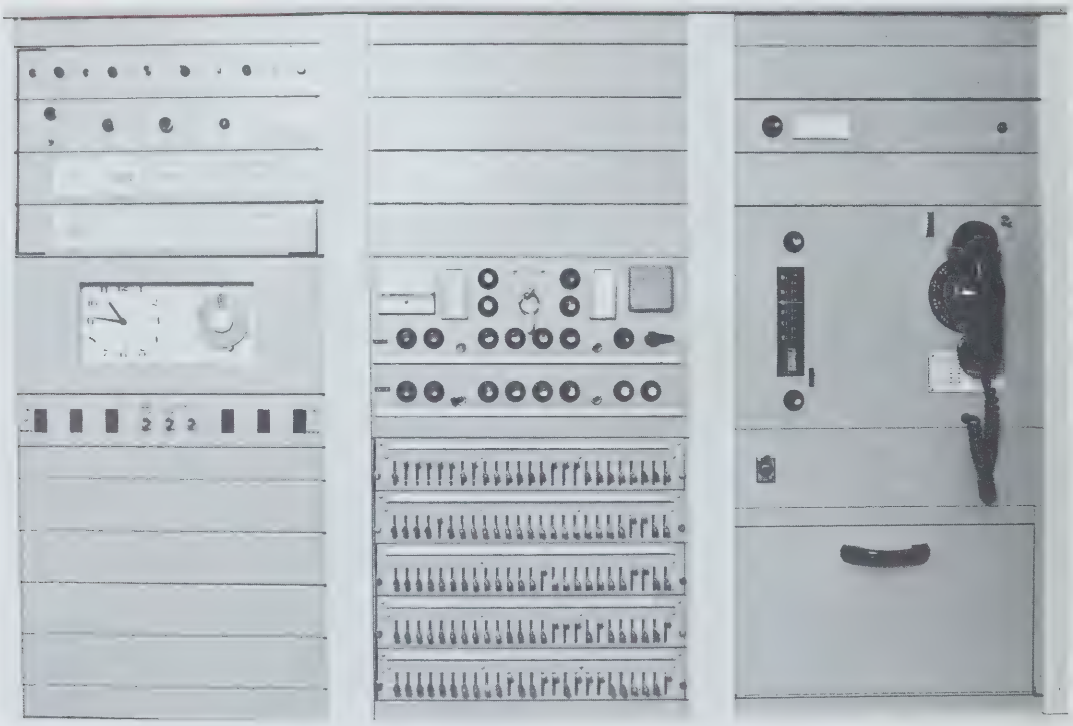
Included in the study should be consideration of the heat pump. Heat pumps optimize efficient energy use by removing heat from internal areas that require cooling and utilizing it in perimeter areas that require heating.

There are two main types of heat pumps, the centralized internal source pump and the decentralized electric-hydronic loop system. The centralized system is usually associated with large buildings where the refrigeration unit is in a central location. The heat extracted from areas requiring cooling is either stored in a water vessel for use at night and/or used to heat areas calling for heat rather than the heat being rejected to the atmosphere through a cooling tower.

The decentralized system utilizes a number of air-conditioning units (water-air heat pumps) connected to a closed loop water system which absorbs the heat from the units on a cooling cycle and rejects the heat from the water to areas requiring heating. This system is supplemented with an electric or fossil-fuel-fired boiler if the water loop temperature is not sufficient for the areas requiring heat.

Alarm and Communication Systems

Communication panel



Fire Alarm Systems
The Ontario Fire Marshal has jurisdiction over fire-protection measures in schools throughout the Province. Other classes of buildings similarly governed are hospitals, university buildings, government buildings, hotels, and theatres. School buildings must also comply with local municipal fire-prevention rules.

The Fire Marshal's regulations are contained in the Ontario Building Fire Safety Design Standard, 1971, a publication of the Ministry of the Solicitor General.

One of these regulations requires an "approved electrically supervised" fire-alarm system in all schools over 6,000 square feet in area or more than two storeys in height. These alarm systems are specially designed for fire-protection purposes and conform with the requirements of the Canadian Standards Association (CSA) and the Underwriters Laboratories of Canada. Examples of the components have been tested by these authorities and bear the labels of one or the other. The systems consist of:

– stations, either "manual pull" type or automatic detectors, which sense either a rapid rise of temperature or fixed high temperatures;

– alarms, which are electric bells, gongs, or hooters;

– a control panel containing relays and power supply;

– an annunciator, indicating the zone or area where the alarm originates;

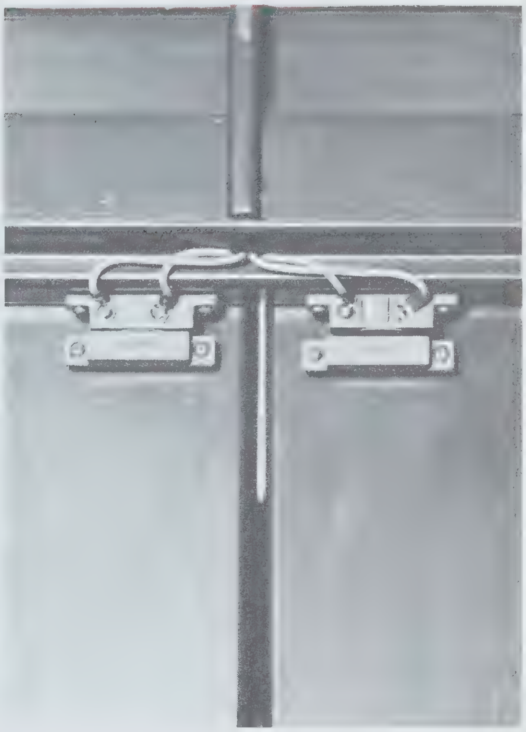
– a secondary power supply, normally required in schools that have over 150,000 square feet of floor area.

The principle of electric supervision is that a fault anywhere in the system will cause a buzzer to ring, allowing it to be promptly identified and dealt with. The fire alarm should also be transmitted to the appropriate agency for action to be taken.

Plans must be submitted to the Fire Marshal and are approved when they meet his requirements. Before the system is accepted, it should be completely checked over by the system manufacturer and certified by him to be correctly installed and in satisfactory operating condition. Often it is then tested while operating by the local fire department. From time to time, the system should be examined and reported on by a competent electrician familiar with such systems.

Multiple security alarm panel

Door switch burglar alarm



Security Systems
Other security systems are available, which give and transmit an alarm to an outside location such as a board office, the police, a fire station, or an independent protection company. Examples of alarm functions often provided are:

– burglar alarms

– low-temperature alarms
Since schools are closed and often unattended during regular and long weekends throughout the winter, they are vulnerable to failures of their heating systems with the attendant damage caused by frost and water. Prompt notification of the low-temperature condition allows time for rectification.

– a power-failure indication. It will give an even earlier warning than the low-temperature alarm, and may be included.

Telephone System
The practice is generally to restrict the use of the telephone system within the building to those people who require the use of the telephone for school business. Pay telephones may be included for student and other staff usage and should be conveniently located throughout the building.

The type of system and the number and location of outlets throughout the school, both initially and including projected growth, are determined by the owner's representative with the Telephone Company. Empty conduit, outlet boxes, and empty panel cabinets are provided in the electrical contract to connect to the telephone service entrance. All wiring and telephone installation work is done by the company.

Public Address and Intercommunication Systems
As a normal requirement, public address systems are provided to allow voice messages, music, or other program material to be dispatched from a central equipment rack or console to individual or groups of learning areas throughout the building.

Main equipment is usually located in the general office and includes the necessary amplifying components and selective switching to allow program material to be sent to an individual learning area, groups of these, or all speakers throughout the school.

Microphone inputs are provided at the main console as well as in designated offices, the stage, and other locations depending on the expected use.

In each learning area, speakers are usually provided of the "talk-back" type with an integral microphone to allow two-way conversation between these spaces and the main

Communication console

console. Room-to-room conversations are not possible, but messages could be relayed through the person at the main rack. A three-position switch is provided in each room to allow reception of messages only (privacy setting), signalling from the learning-area to the main rack, and an off position. The switch should be located out of normal student traffic patterns to prevent misuse of the switches by the students, especially between periods. Speakers are normally located above the chalkboards at the front of the learning area or at the front of the side wall. Speakers in the corridors are also provided, but without the talk-back features.

In areas where high ambient noise levels are often encountered, speaker horns are provided, with volume controls and a supplementary handset which, when operated, cuts off the speaker and allows for a two-way conversation.

In large spaces such as the cafeteria or gymnasium, multi-speaker coverage is provided to allow clear, even sound coverage throughout the space. In the gymnasium, speakers should have wire-guard protection against damage. Speakers, if installed outside the building, should be of a weatherproof type.

Clock or other program signals can be transmitted over the public address system by interconnection of the program equipment with the P.A. system. A weatherproof speaker can also be provided at a receiving entrance to allow for remote identification of persons at that entrance during day or night operation.

An intercom system can be used instead of, or to supplement, the public address system as previously described, by providing a telephone-type handset in each learning area, office, and maintenance centre.

The cheapest system is a simple one, allowing for a conversation between any branch phone and the central equipment at the main desk.

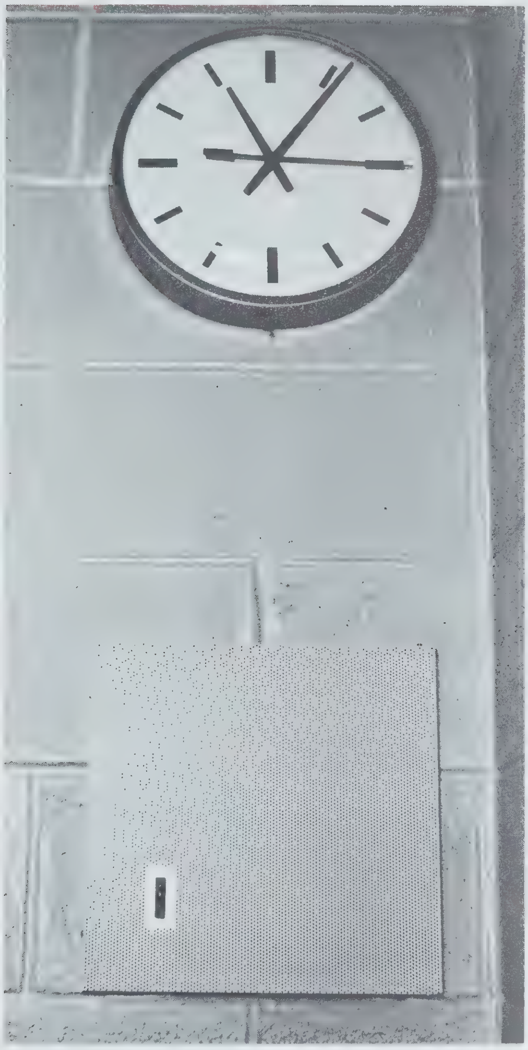
If the total number of telephones is not large, an "all-talk" system is available, with common talking throughout all phones. With this system, conversation between learning areas is possible. Signalling of the station to be contacted is the limiting factor in this system, since it involves separate push buttons and buzzer-signal wiring.

With larger systems, where privacy is required in conversations, or where room-to-room conversations and signalling are required, a more sophisticated system can be employed with central switching equipment. This is more expensive and will require space for the central equipment.

In gymnatoriums and cafetoriums, the normal speakers included in the public address system may not be of a sufficiently high standard for the programs that are often required in this type of space. In these instances, direct sound from the front of the room is preferable, with speakers located at the stage rather than distribution through the speakers in the ceiling. Such systems usually involve separate amplifiers with input provisions for a tape, radio, movie projector, microphone, and TV sound. Alternatively, these systems can input to the school's public address system.

Throughout the sound systems, good quality equipment should be employed, and the wiring should be of a high standard so that ease of maintenance is possible and alterations can be easily carried out.

P/a speaker and clock



Clock and Program Systems

Automatic clock systems are normally provided in new schools, especially in larger schools where correction of clocks could be a major time-consumer for maintenance staff, in the event of power failure.

Clocks are usually provided in all enclosed learning areas, as well as double-faced clocks in the corridors and open space areas. In the enclosed learning areas, it is preferable for the clock to be visible to all people; it is frequently mounted on the side wall of the room above the entry door.

Clock systems usually employ a master clock, electrically operated with provision for the clock to continue running during a power failure. The master clock controls all clocks throughout the building. Such systems are of the following types:

– minute-impulse type with its own wiring system. The minute hand on these clocks jumps one minute at the end of each minute and no sweep second hand is available.

– synchronous type with its own wiring system, but having a sweep second hand.

– high frequency type with a high frequency signal generator feeding into the regular electric system in the building, and allowing secondary clocks to be installed anywhere in the building without requiring its own wiring system.

An economical type of installation uses an electrically driven sychronous clock in each location, but with a separate wiring system allowing simultaneous correction from a central point. This system does not require a master clock.

A program system can be used in conjunction with the master-clock system and with program wiring installed in common conduit with the clock wiring and, in some cases, using common wiring. The program control unit is adjustable to allow programs to be changed from time to time. It should be established whether the program will repeat on a twenty-four hour basis or on a one-week basis, as this will affect the choice of equipment.

The program system normally operates bells in corridors, outside the building, and in areas with high noise levels. In learning areas and other individual rooms, program buzzers are located in the clock or in the outlet box that services the clock. Sometimes visual signals or tones are preferred to buzzers.

Normally, four separate programs are available on any one program originator, although six programs can be obtained at additional cost. Some consideration should be given as to whether different programs are required in different areas of the building. If so, the wiring will have to be installed so that programs can be directed accordingly.

The program controller is normally mounted next to the master clock.

Sports timers in the gymnasium, with input provisions from the scorer's desk, are sometimes provided. These are separate provisions and are not connected to the clock system.

Television

Where the use of television as a teaching aid is contemplated in a school, the extent of the initial provisions will have to be carefully considered. There should be sufficient flexibility

in the design of the building to allow future installation of, or revision to, the TV cable distribution. Accessible ceiling spaces would provide such flexibility. However, where ceilings are inaccessible, an empty conduit is recommended with outlets in each learning area.

The types of programs that might be used in a learning area are "off-air" programs either from commercial channels or from the local ETV (educational television) station or from programs that are originated in the school and distributed "live" or by videotape. At present, there is only one ETV channel in use in most locations, and the program schedule used by the ETV stations in most cases is not always convenient for class usage. As a result, VTR (videotape recordings) are made of these programs for distribution in the school at a more convenient time.

A central room may be provided for the audio-visual department from which TV programs can be distributed. This room will serve as the distribution centre and will also serve as a location for storing and repairing equipment, as a tape library, and as a place where tapes can be prepared. Central videotape recording equipment can also be located at this point for the recording of live programs from other points in the school.

If the area in which the school is located is served by cable TV, a connection to that system is possible. If not, an antenna with head-end equipment should be installed. The installation should conform to the Department of Communication requirements for cable TV to allow for future connection to cable TV without expense at that time.

Colour TV might also be considered, as many manufacturers of TV educational equipment no longer make black and white units.

The distribution system can initially be for VHF (very high frequency) distribution, but should be designed to allow ulitmate inclusion of UHF (ultrahigh frequency). Cable suitable for UHF should be installed.

Two types of cable distribution systems are available: the RF (radio frequency) system or the video system. In the RF system, all outlets are connected to one cable, with each learning area able to select any of the channels in use. Programs are run on a schedule, and a learning area has the option of using or not using the program being scheduled. It is noted that "in-house" programs can be initiated on unused channels.

The video system has a radial distribution system, with each learning area connected on separate conduit and wiring from the distribution centre. With this system, a learning area requests a program, and a program is dispatched from the distribution centre. The control of the program is from the distribution centre. This is a much more expensive system, costing approximately ten times the cost of the RF system and is more commonly used in universities where a wider range of program selection is required and where better resolution at the monitor set is necessary.

If temporary and portable equipment is to be used, the TV outlets should be mounted low in the room with an adjacent power outlet. Ceiling-mounted sets are convenient and less subject to damage. Note that these sets should be located with respect to high-glare sources so that reflections cannot be seen in the glass front of the set. Outlets will be normally mounted adjacent to the window wall.

The outlets in the learning area can be one-way for reception of TV only or two-way, allowing reception as well as transmission of a program to the distribution centre or to other areas of the building. The two-way outlet is a compromise and may, however, jeopardize reception. As this outlet involves additional expense, it is definitely not recommended for normal learning areas unless it is known that programs may be originated in these rooms.

This would normally apply to the laboratory, gymnasium, and cafetorium. If there are not many areas where programs will be originated, then it is recommended that separate lines for program origination outlets be provided at these locations and that normal antenna provisions also be included in these areas.

Some method of communication between the learning areas and the TV distribution room should be considered, especially where unscheduled programs may be available on unused channels for individual rooms. The TV intercom equipment can be the plug-in, portable type and, with the addition of a small amount of wiring, it can also include on-off switching of the videotape at the TV centre to allow the teacher to co-ordinate the projection of the videotape with other audio-visual equipment at the learning area.

Lightning Protection

Lightning is caused by the release of stored electrical energy in a thundercloud to the ground. A thundercloud is, in fact, an electrical cell or combination of cells. It tends to be negatively charged at the base and positively charged at the top. Lightning is usually formed by a stepped leader process proceeding from the base of the cloud towards the ground. As the leader approaches the ground it induces a high positive potential in the earth below it, which results in a positive return streamer flowing upwards from the ground to the stepped leader. This action occurs at a much faster rate than the downstroke because of the formation of an ionized path by the stepped leader. The contact between the stepped leader tip and the upward return streamer results in a discharge of enormous energy at the ground, involving voltages counted in the millions. A return streamer may carry currents as large as 200,000 amperes, although just over 10% of this is usual. These currents are maximum in about 10 microseconds.

Few people realize that water, either *in* the material or *on* it, is turned into steam, in this very short period of time, by the heat generated by the discharge. The rate of expansion of the gas created is explosive and this, in fact, is the cause of much of the damage associated with lightning.

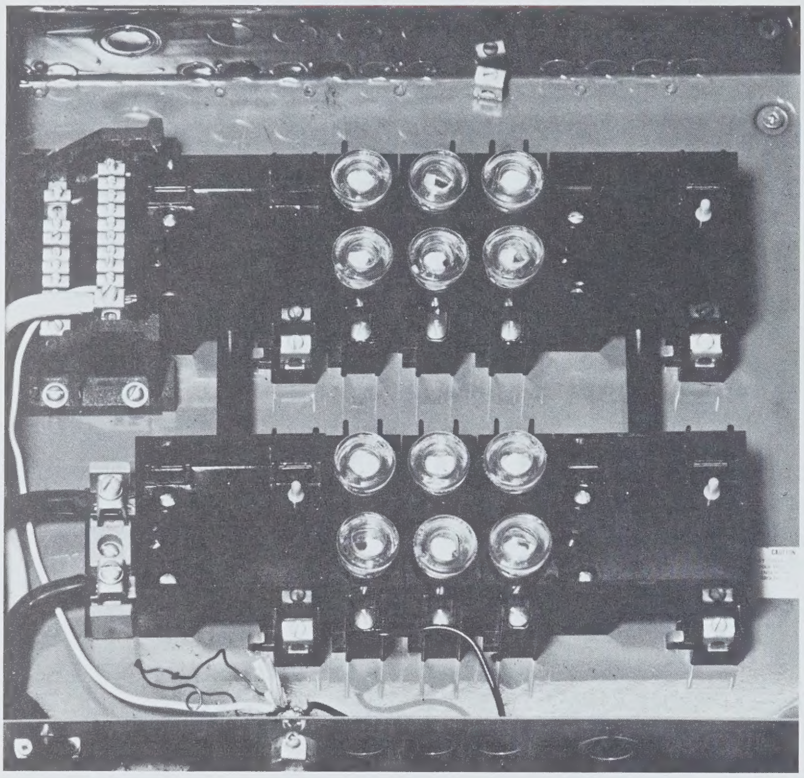
Damage can be considerable and, for this reason, some protective measures are necessary. Buildings in Ontario are required to have protection, more or less depending on their exposure, in conformity with provincial legislation entitled the Lightning Rods Act. The principle upon which the required protection is based is that a lightning rod, a kind of metal spear mounted above the top of the building and connected to the ground by a low resistance conductor, provides an easy path for the electric discharge from the sky and allows it to pass harmlessly to the ground.

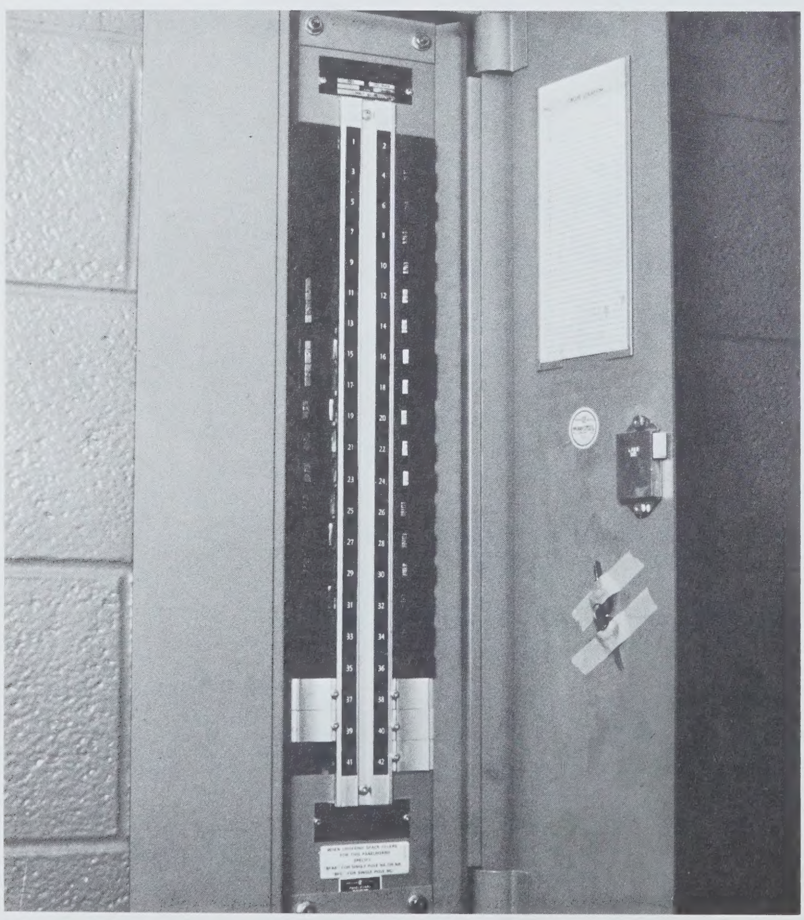
Regulations under the Lightning Rods Act prescribe point spacing for various types and arrangements of buildings, conductor sizes for down leads, and required grounding arrangements. The grounding system is most important and is required to be kept separate from grounds required for other electric apparatus and systems. It normally consists of copper plates or wires buried at such depth as to be in moist earth at all times.

Certain contractors are licensed under the Act to install lightning-protection systems and, for this reason, lightning protection is often considered a separate trade from other electrical work. However, it may be proper to include it with other electrical work in the case of more elaborate buildings where conduit work for the system must be installed as the work progresses.

Terminology

Top: Fuses
Bottom: Circuit breaker





For those persons unfamiliar with the technical language contained in the text, the following explanatory notes and definitions may be useful.

Electric Services Section

Conductors: wires, cables, or bars (called bus bars), made of metals that have a low electric resistance to minimize transmission losses, e.g., copper or aluminum.

Protective over-current devices: fuses that melt and interrupt the flow of electric current and circuit breakers that open by electromagnetic or thermal action when the rating of the conductor is exceeded. With a few very minor exceptions, a switch is also required. These switch and protective device combinations, singly or collectively, are called switchgear.

Faults and short circuits: a fault is an accidentally formed path for an electric flow between phase wires of a system or between one or more of the phase wires and the ground. The establishment of electric flow through this path is called a short circuit.

Load: the amount of electric power that is being used in an electric system at any instant. For a building or a substantial part thereof it will be expressed in kilowatts (KW.).

Lighting Section

Footcandle: a footcandle is the measure of illumination at a point on a surface that is one foot from and perpendicular to a point light source of one candle. Footcandle readings are used to indicate the illumination of a specific point for the average illumination on a surface.

Dekalux: this is an SI unit equal to 1.076 footcandles. One dekalux equals ten lux.

Brightness: the brightness of a light source is measured in candles per square inch for a very bright source and in footcandles for a reflecting surface. Several meters are available for the measurement of brightness; however, these are not as often used or are not as readily available as the footcandle meter.

Lumen: the total output of a light source falling on a surface one square foot in area, every part of which is one foot from a point source having a luminous intensity of one candle in all directions.